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Continued on the Last Page

(54) [Title of the Invention] Semiconductor Device and Manufacturing Method thereof

(57) [ABSTRACT]

[Object] Semiconductor devices have been made multifunctional year by year, while thinner and lighter semiconductor devices have been developed, and in order to achieve the purpose, integration into limited space as well as thinner elements have been required. For example, IC cards have been made multifunctional year by year, while the area of the IC card is too limited to arrange in a planar manner elements for achieving each function, thereby limiting integration.

[Solving Means] The present invention provides a semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that some or all of the respective elements are stacked in the thickness direction.

[Scope of Claims]

[Claim 1] A semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that some or all of the respective elements are stacked in the thickness direction.

[Claim 2] A semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that the semiconductor device is manufactured by providing the respective elements and wiring on a foldable substrate and folding the substrate.

[Claim 3] A semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that the semiconductor device is manufactured by forming multiple units which are each provided with the element and wiring on the substrate and have a specific function and combining and stacking the units.

[Claim 4] A semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that the semiconductor device is manufactured by rolling up a semiconductor device with the element composed of a flexible material and wiring formed on a flexible substrate.

[Claim 5] A semiconductor device comprising all or some of an element for recording data, a logic element for performing data processing, a communication element for exchanging data, an element for storing or generating energy, an element for detecting and accumulating external information or converting the external information into data that is able to be communicated, and an element for displaying the stored data, characterized in that components which have a width corresponding to the thickness of the semiconductor device and the same length as one side of the semiconductor device in the form of a plate are provided, the elements constituting the semiconductor device are mounted on one of the components or are divided and mounted on a plurality of components, and one semiconductor device is formed by combining the respective components.

[Claim 6] The semiconductor device according to any one of claims 1 to 5, characterized in that the element for recording data, the logic element for performing data processing, or the communication element for exchanging data is composed of a three-terminal element comprising an organic semiconductor, an organic insulator, and an organic conductor.

[Claim 7] The semiconductor device according to any one of claims 1 to 6, characterized in that the element for displaying data is composed of a three-terminal element or a two-terminal element comprising an organic semiconductor, an organic insulator, and an organic conductor.

[Claim 8] The semiconductor device according to any one of claims 1 to 7, characterized in that the respective elements constituting the semiconductor element all comprises organic materials.

[Claim 9] A method for manufacturing the semiconductor device according to any one of claims 6 to 8, characterized in that the step of forming the organic transistor is a coating method, a printing method, or a film bonding method.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to semiconductor devices, including credit cards, bank cash cards, cards for use in applications such as electronic money, configured to include all or some of IC memories capable of recording/reading fixed information and variable information, processors, display elements, external interfaces, and sensors as basic configurations.

[0002]

[Prior Art] The basic configurations of semiconductor devices, including conventional IC cards, include storage elements dedicated to fixed information, storage elements as represented by RAMs, etc., on which information can be rewritten, if necessary, external interfaces such as RF coils and connectors, processors for exercising control of the storage element and the interface and performing various types of processing of the stored data, and power supply systems such as lithium ion batteries. The storage elements and the processors are composed of inorganic semiconductors such as Si, which are bonded to a resin substrate and wired by wire bonding. FIG. 1 shows an example of the structure of a conventional semiconductor device with reference to an IC card as an example. The basic configuration includes a storage element 4 (a ROM dedicated to fixed information, a RAM on which information can be rewritten), an external interface such as a RF coil 5 and a connector, a processor 3 for exercising control the storage element 4 and the interface and performing various types of processing of data, and a source of energy supply such as the RF coil 5 and a lithium ion battery. These components are on either side of a substrate 6 in a planar manner, and are connected via a wiring 11. The storage element 4 and the processor 3 are composed of inorganic semiconductors such as Si and made into one chip to form an IC chip, and the IC chip 20 is bonded to the resin substrate 3 and wired by wire bonding.

[0003] In recent years, development for obtaining multifunctional devices has been also carried out by mounting elements besides the basic configuration. For example, examples of IC cards include displays (for example, Japanese Patent Laid-Open No. 62-8838), keyboards (for example, Japanese Patent Laid-Open No. 61-43749), batteries (for example, Japanese Patent Laid-Open No. 2-33198), and sensors (for example, Japanese Patent Laid-Open No. 1-175691). As for the display function, IC cards provided with display elements such as display elements using reversible thermal recording materials (for example, Japanese Patent Laid-Open No. 4-105996) and liquid crystal display elements (for example, Japanese Utility Model Official Information No. 3-9078) have also been created in order to display stored information on the IC cards. As the sensor function, there are various types of sensors mounted on one IC card for boosting convenience (for example, Japanese Patent Laid-Open No. 1-175691) and sensors for authenticating the card holders (for example, Japanese Patent Laid-Open No. 64-38295). Furthermore, a technique for applying, as a high-density memory, an IC card with functions stacked and mounted thereon is disclosed in Japanese Patent Laid-Open No. 8-31184.

[0004] Moreover, as for the mount technology of arranging elements on a flexible sheet substrate and folding the substrate, for example, the mount technology is disclosed in for example, Japanese Patent Laid-Open No. 11-134459, in which a spiral conductor pattern is formed and folded in order to make the effective length of an RF coil of an IC card as long as possible, and the technology is disclosed in for example, Japanese Patent Laid-Open No. 6-64383, in which a film substrate with elements mounted thereon is folded into two, and the overlapped edges are provided with a lead in such a way that only one edge of the IC card is mechanically and electrically connected.

[0005]

[Problem to be solved by the Invention] Semiconductor devices have been made multifunctional year by year, while thinner and lighter semiconductor devices have been developed, and in order to achieve the purpose, integration into limited space as well as thinner elements have been required. For example, IC cards have been made multifunctional year by year, while the area of the IC card is too limited (JIS X-6301 specifications: 54 mm × 85.6 mm) to arrange in a planar manner elements for achieving each function, thereby limiting integration. Although there is also an arrangement method by stacking, the thickness is also limited (JIS X-6301

specifications: 0.25 mm, 0.76 mm). Therefore, the method of merely stacking isolated elements with respective functions has limitations because of the large thickness of each element.

[0006] Although the substrate of a Si element for use in the semiconductor device can also be made thinner to achieve the element thinner, the element will be broken down easily. For example, IC cards are stored in card holders, wallets, or the like for carry, but can be often bent or twisted by external forces in pockets, bags, or the like, and are thus required to be flexible and unlikely to be destroyed. Furthermore, since the element needs to be bonded to a resin substrate and wired by wire bonding, the IC cards have problems which significantly decrease the reliability, such as destruction of the element itself or wiring due to bending or twisting.

[0007] Conventional semiconductor devices use storage elements and processors with the use of Si semiconductors. Therefore, the semiconductor devices have a problem in that the manufacture of the elements themselves requires complex steps and also requires large-scale expensive apparatuses, thereby resulting in expensiveness in cost.

[0008] Furthermore, the storage elements and processors with the use of Si semiconductors have a problem that the performance of the elements is significantly degraded due to a slight amount of contaminant.

[0009] Even if various types of functions can be mounted on one semiconductor device, the combination of required functions differ depending on the users. The prior art requires complex steps which differ from each other for each element, and requires large-scale expensive apparatuses, thereby resulting in expensiveness in the entire production cost. Therefore, no profit can be made unless one type of commercial product is produced in large numbers. Thus, it has not been possible to respond sensitively to the specifications desired by each user.

[0010] As a typical way for displaying information on an extremely thin semiconductor device such as an IC card, display elements using reversible thermal recording materials (for example, Japanese Patent Laid-Open No. 4-105996) can be cited. However, the display elements require an apparatus provided with a thermal head for writing/erasing, and the IC card is by itself not capable of displaying, erasing, or rewriting information freely. Furthermore, IC cards provided with liquid crystal display elements (for example, Japanese Utility Model Official Information No. 3-9078) have also been created. However, the need to enclose the liquid renders the process complex, resulting in an increase in thickness due to a window material for sealing.

[0011] For the power supplies of conventional semiconductor devices, secondary batteries such as lithium ions and lithium polymers, silicon solar cells, etc. are used, and power supply via RF is also utilized for IC cards. However, secondary batteries require the operation for charging and special equipment for charging, and operations such as periodical replacement of the batteries are also required. Solar cells requires no special operation for electric power generation, and have long lifetimes. However, silicon solar cells have poor flexibility in flexibility. The power supply via RF is not able to be used unless when used, there is nearby a power supply source with the use of micro waves.

[0012] Although a technique for applying, as a high-density memory, an IC card with functions stacked and mounted thereon is disclosed in Japanese Patent Laid-Open No. 8-31184, the technique is limited to for recording of information such as by stacking a photoconductive layer which serves as an input and a polymer dispersed liquid crystal layer which serves as a storage in recording of information, and is not able to be applied to stacking other functions. Furthermore, the mount technology disclosed in Japanese Patent Laid-Open No. 11-134459, of arranging elements on a flexible sheet substrate and folding the substrate is a mount technology of folding just a spiral pattern of conductor in order to make the effective length of an RF coil of an IC card as long as possible. The technology disclosed in Japanese Patent Laid-Open No. 6-64383, in which a film substrate with elements mounted thereon is folded into two, and the overlapped edges are provided with a lead in such a way that only one edge of the IC card is mechanically and electrically connected, is a mount technology in which individual components are mounted with the use of solder or the like and the substrate is folded into only two. Due to the

thicknesses of the individual components themselves and the thickness required for mounting onto the substrate (such as solder or lead pins), the number of layers stacked is limited.

[0013]

[Means for Solving the Problem] The entire semiconductor device can be made flexible and less prone to destruction by respective portions constituting the semiconductor device composed of high flexible materials against bending or twisting. In this regard, for example, organic materials generally have higher flexibility, are less prone to fracture or destruction if bended, and have high durability against repeated bending, as compared with inorganic semiconductor crystals and metals. In recent years, organic materials as conductors, which have conductivities close to those of metals, have been also developed, organic materials as semiconductor materials, which have characteristics comparable to those of amorphous silicon, have been also developed, and the use of these organic materials has allowed semiconductor elements to be manufactured with the use of organic materials. Furthermore, organic materials have a slight amount of impurity which less affects the properties of the elements, and is more flexible, as compared with inorganic semiconductor materials. Therefore, the occurrence of the problem that the reliability of the semiconductor device is significantly decreased due to contamination, bending, twisting, etc. can be reduced by all of or as many components as possible from among the components of the semiconductor device, which are composed of organic materials.

[0014] Furthermore, with organic materials dissolved in appropriate solvents or put into a liquid by gelation, a film of any shape can be formed by printing such as screen printing or inkjet with the use of this liquid. In the printing process, the appropriate selection of the organic materials and the solvent allows a thin film composed of a type of organic material to be stacked on a thin film once manufactured and composed of another organic material, and also easily allows devices composed of a stack of different types of materials and a stack of different types of devices to be manufactured. This allows respective elements constituting a semiconductor device, such as storage elements, processors, display elements, power supplies, external interfaces, and various types of sensors, not only to be arranged in a planar manner, but also to have the total thickness made thinner while stacking in the thickness direction, allowing for more functions provided in the limited space of the semiconductor device than ever before.

[0015] Specific methods for the stacking include the following.

[0016] Firstly, a structure in which elements to be configured are stacked in the thickness direction can be formed by forming the respective elements in a planar arrangement on a sheet of substrate, folding the substrate into a final shape after wiring, and then sealing openings at the ends, if necessary. In this case, as for the initial arrangement of the respective elements on the sheet substrate, it is necessary to arrange the respective elements appropriately in consideration of the positional relation among the respective elements in the final folded shape. Furthermore, in a case in which elements come in direct contact with each other when folded, the elements can be coated with a protective film in advance to avoid direct contact.

[0017] As a second method for stacking, a method is provided of manufacturing in advance units with elements arranged on sheet substrates, combining and stacking units (sheets) with required functions from among the units, and providing wiring connections. The device can be used as a sheet of device by sealing the ends (openings), or can be used in an opened state or a closed state, if necessary, by making the device openable and closable as needed without sealing.

[0018] As a third method for stacking, a method is provided of forming respective elements on a sheet of substrate in a planar arrangement, and after wiring, rolling up the substrate into a final shape.

[0019] As a third method for stacking, a method is provided of, in a case in which there are components which have a width corresponding to the thickness of the semiconductor device and the same length as one side of the semiconductor device (with an appropriate thickness) in the form of a plate, and the elements constituting the semiconductor device are mounted on one of the components, or are divided and mounted on a plurality of

components, forming one semiconductor device by combining the respective components in a direction perpendicular to the thickness direction of the final semiconductor device.

[0020] Furthermore, two or more of the first to fourth methods can be combined to form a stacked structure.

[0021] Methods for wiring between the respective layers include the following methods.

[0022] Firstly, a method is provided of providing wiring through a through hole created to pass through the substrate of each layer. Secondly, a method is provided of forming in advance terminals for each layer so as to be positionally aligned with the upper and lower layers with the terminal interposed therebetween a terminal, and making the terminals stick together when stacked. Thirdly, a method is provided of providing in advance a light-emitting element and a light receiving element in each layer, and exchanging data via light.

[0023] As a method for mounting a large number of functions desired to occupy a large portion of the surface, it is possible to manufacture multiple functional portions on a sheet of foldable substrate, to fold the substrate into n for storage and carry, and in use, to use the device folded so that the functional portions to be used lie at the top. Furthermore, folding the device in such a way that two or more functional portions to be used simultaneously are arranged vertically or laterally can also allow the device to be user-friendly.

[0024] Furthermore, a wide variety of elements can be manufactured in a consistent printing process by composing almost all of the elements of organic materials, thereby resulting in a quite simple manufacturing process at low cost. Semiconductor devices can be inexpensively manufactured with simple equipment in the consistent process, allowing for dealing with small-lot production of a wide variety of different products in specification at user's request. Furthermore, it is also possible to respond to user's requests sensitively by the method of manufacturing in advance functional units with elements arranged on sheet substrates, combining and stacking units with functions desired by the user from among the units, and providing wiring connections. These devices can be formed by sticking sheet films together.

[0025] Moreover, as a method for customizing the functions at user's request, a method is also provided of manufacturing in advance a semiconductor device with as many functions as possible provided, and rendering only the functions desired by the user available or rendering the unnecessary functions unavailable.

[0026] As for the display element, extremely thin displays have also been achieved in recent years by use of a printing process, in such a way that organic electroluminescence, electrophoresis, or the like is combined with a driver circuit using an organic semiconductor and an organic conductor. The displays mounted on semiconductor devices such as IC cards can achieve semiconductor devices with high flexibility in shape, with high durability and reliability against external forces such as bending and twisting, and with the ability to display information by themselves, which have not been feasible conventionally. As a driving circuit for the display element, active matrix driving via three-terminal elements such as a thin film transistor (TFT) or two-terminal elements such as a MIM element, or simple matrix driving via a structure in which a display layer is sandwiched between electrodes arranged vertically and horizontally in a grid is used. These driving circuits are manufactured with a combination of conductor, semiconductor, and insulator materials, to which flexibility can be provided by using organic materials for all or some of the materials.

[0027] The use of a solar cell using an organic material can provide a power supply which has a long lifetime and high flexibility in shape without the need of any special operations for electric power generation or charging.

[0028] The use of a secondary battery using polyelectrolyte or an electrolytic capacitor using an organic conductor can store energy generated by a solar cell and energy externally supplied with the use of RF.

[0029] The simple process such as printing allows multiple functional portions (such as sensors) to be integrated or stacked and allows information of multiple types to be simultaneously or sequentially detected. The use of the information of multiple types, for example, for person authentication allows a high information recognition accuracy to be obtained through crosscheck of the information of multiple types, although the security may be broken in authentication from only one piece of information such as a password or a fingerprint.

[0030]

[Embodiment Modes of the Invention] The present invention will be described below with reference to embodiments thereof. However, the present invention is not to be considered limited to the embodiments.

[0031] (Embodiment Mode 1) FIG. 2 shows an IC card taken as an example of an embodiment of the present invention, which corresponds to an example in which respective components are sequentially formed on a substrate surface. Specifically, in the embodiment, the IC card is formed by stacking, on a sheet-shaped substrate 6, a processor 3 as a logic element for performing data processing, a storage element 4 as an element for recording data, a RF coil 5 as a communication element for exchanging data, a first sensor 1a as an element for detecting and accumulating external information, a second sensor 1b as an element for converting external information into data that is able to be communicated, and a display element 2 composed of a driving circuit 2b and a display layer 2a as elements for displaying the recorded data in the thickness direction of the elements. These elements are protected by a protective film. In the example, the two types of sensors 1a and 1b are stacked to each other, and the storage element 4 and the display element 2 are also stacked to each other. However, it is to be noted that the types and number of the elements to be stacked are not limited to the present embodiment. As long as the elements required are provided depending on functions used, it is not necessary to provide elements for all of the functions. Furthermore, stacking is not necessary for all of the elements, and stacking may be carried out for some of the elements.

[0032] Furthermore, not shown in the figures in the embodiment, the IC card described above may have an element composed of an organic solar cell for generating energy or an element such as a polymer cell or an electrolytic capacitor of an organic semiconductor for storing energy, provided on the substrate.

[0033] Moreover, the embodiment mode with the stacked structure is not limited to IC cards, and is also applied to, for example, televisions, cellular phones, personal digital assistants, etc.

[0034] FIG. 3 (a) shows a specific example of a method for manufacturing an organic transistor as a three-terminal element, which forms the display element 2, the driving circuit 2b, the storage element 4, and the processor 3. First, the surface of the substrate 6 composed of a polyimide is subjected to a hydrophilization treatment. Methods for the hydrophilization treatment includes, for example, a method via ultraviolet light irradiation (wavelengths: 172, 222 nm) in vacuum under a water vapor atmosphere. On the substrate subjected to the hydrophilization treatment, a solution of a conducting polymer is applied in accordance with wiring patterns and dried by inkjet printing to form electrode patterns for a source electrode 23 and a drain electrode 24. As the conducting polymer, a 1.5 wt% aqueous solution (Baytron P) of a mixture of poly-ethylenedioxythiophene (PEDOT) and poly-stylenesulfonate (PSS) is used, resulting in a thickness of about 500 nm. A solution of Fluorene-Bithiophene copolymer in xylene is used to form a p-type organic semiconductor layer 25 about 50 nm in thickness thereon by spin coating. A solution of Poly-vinylphenol (PVP) in isopropanol is used to form an insulating layer 22 about 500 nm thereon by spin coating.

[0035] A gate electrode 21 composed of a conducting polymer is formed on this insulating layer so as to be formed over the channel portion. As the conducting polymer, a 1.5 wt% aqueous solution (Baytron P) of a mixture of poly-ethylenedioxythiophene (PEDOT) and poly-stylenesulfonate (PSS) is used in the same way as for the source electrode 23 and the drain electrode 24, resulting in a thickness of about 500 nm.

[0036] In a case in which wiring is required from the drain electrode in a transistor or the like for a display element driving circuit to a pixel of a display layer formed by stacking over the driving circuit, the drain electrode can be connected to each pixel of the display element by use of a method for forming a through hole running through the insulating layer and the semiconductor layer from the drain electrode and a method for manufacturing both the insulating and the semiconductor layer by inkjet.

[0037] Alternatively, as another method, there is a method of formation in the order of a gate electrode 21, an insulating layer 22, a source electrode 23, a drain electrode 24, and a semiconductor layer 25 as shown in FIG. 3(b), which is the reverse order relative to the previous mentioned method for manufacturing a transistor.

[0038] As a driving circuit for the display element, it is also possible to use active matrix driving via, besides three-terminal elements such as the transistor, two-terminal elements which have a structure in which an insulating layer is sandwiched between two terminals composed of conductors and have a switching function, such as MIM elements, or simple matrix driving via a structure in which a display layer is sandwiched between electrodes arranged vertically and horizontally in a grid.

[0039] A polymer dispersed liquid crystal is used as the display element. However, the display element is not limited to liquid crystals, and for example, an electrophoretic element or an organic electroluminescence (organic EL) element is used. The liquid crystal for use in the polymer dispersed liquid crystal layer is not particularly limited for its type. For example, nematic liquid crystals, smectic liquid crystals, cholesteric liquid crystals, etc. can be preferably used. As the polymer for use in the polymer dispersed liquid crystal layer in the present invention, polyvinyl butyral, polyester, polyurethane, acrylic, acrylic silicon, vinyl chloride, a vinyl acetate copolymer, a silicone resin, polyvinyl alcohol, polyvinyl pyrrolidone, a variety of cyanoethyl compounds such as cyanoethylated pullulan, a plurality of polymer resins such as an epoxy resin, and mixtures thereof can be used. The method for forming the polymer dispersed liquid crystal layer according to the present invention is not particularly limited. All of methods for forming liquid crystals, which are known to one skilled in the art and are commonly and/or regularly used by one skilled in the art can be used in the present invention. For example, methods such as encapsulation, polymerization-induced phase separation, thermally-induced phase separation, solvent-induced phase separation can be appropriately used.

[0040] In the case of storage elements such as ROMs and RAMs, the storage elements can be achieved, for example, by adding a capacitor composed of a ferroelectric material to the drain side of the transistor mentioned above. As an organic ferroelectric material, for example, a vinylidene chloride-trifluoroethylene copolymer can be used to form a thin film by spin coating or inkjet.

[0041] Optical image sensor can also be achieved by utilizing an array which has an organic transistor structure. When a gate electrode of a transistor corresponding to each pixel is composed of a material which generates carriers by light (also including infrared rays), carriers will be generated in the gate portion depending on the intensity of the light. Thus, the source-drain current which varies depending on the generated carriers is detected for each pixel for imaging. As the material, for example, porphyrins, phthalocyanines and derivatives thereof, mixtures of polyphenylene vinylene derivatives and fullerene derivatives, perylene derivatives etc. can be used.

[0042] The RF coil 5 can be manufactured, for example, by screen printing with a conductive paste containing metallic fine particles as its main constituent. In the present embodiment, a silver paste (composed of silver powder with an average particle size of 10 μm , a phenoxy resin, and butyl carbitol) is used to be printed in a coil shape by screen printing, and then dried at 150 $^{\circ}\text{C}$ for about 20 minutes. The coil turns is 20, the line width is about 300 μm , and the total length is about 250 cm.

[0043] In the case of any elements in direct contact with each other, the elements can also be coated with a protective film or the like in advance to prevent direct contact.

[0044] (Embodiment Mode 2) FIG. 4 shows an IC card taken as an example of an embodiment of the present invention. On a sheet-shaped substrate 6, a processor 3, a storage element 4, an RF coil 5, a first sensor 1a, a second sensor 1b, and a display element 2 are each arranged and formed in a planar manner, and the substrate 6 is folded after completing wiring 11 to obtain the shape of a final IC card. Then, sealing an opening at the end, if necessary, can form a structure in which the elements constituting the IC card are stacked in the thickness direction of the IC card. The present embodiment corresponds to a case of an IC card folded into four, and in FIG. 4, the substrate divided in quarters has the processor 3 and the storage element 4 arranged on the top-left

section, the second sensor 1b arranged on the bottom-left section, the RF coil 5 arranged on the top-right section, and the first sensor 1a and the display element 2 arranged on the bottom-right section, in such away that the RF coil 5, the first sensor 1a, and the display element 2 line on the outermost surfaces when folded. Although FIG. 4 shows a rectangle sealing portion 9, the shape of the sealing portion 9 is not particular limited. The respective elements can be manufactured by, for example, the method described in Embodiment 1. It is desirable to arrange the respective elements so as to be kept away from the folded line, and the wiring 11 is composed of a flexible material.

[0045] In a case in which there are any elements on the outermost surfaces or any elements in direct contact with each other, the elements can be coated in advance with a protective film or the like.

[0046] Furthermore, the present method can be employed for not only devices mainly including elements composed of organic materials as in Embodiment 1, but also inorganic semiconductor devices such as silicon devices with processors and memories arranged on substrates, which are made thinner by removing substrates without any functional portions as much as possible.

[0047] The present method is not limited to for IC cards, and is applied to other semiconductor devices, for example, televisions, cellular phones, personal digital assistants etc.

[0048] (Embodiment Mode 3) FIG. 5 is an embodiment which shows an example in the case of achieving a stacked structure by manufacturing in advance functional units with elements and wirings arranged on substrates, combining and stacking units (sheets) with required functions from among the functional units, providing wiring connections, and providing sealing in order to integrate the respective layers. FIG. 5 is an example in which a processor 3 and a storage element 4 as a first unit C, a second sensor 1b as a second unit B, a RF coil 5 as a third unit D, and a first sensor 1a and a display element 2 as a fourth unit A are arranged on separate substrates 8 and stacked in such a way that the third unit composed of the RF coil 5 and the fourth unit composed of the first sensor 1a and the display element 2 line on the outermost surfaces when stacked, and sealing 9 is provided. Although FIG. 5 shows a rectangle sealing portion 9, the shape of the sealing portion 9 is not particular limited. The respective elements can be manufactured by, for example, the method described in Embodiment 1. As a method for wiring between the upper and lower sheets, for example, a method with the use of a flexible printed wiring (FPC), a method in which wirings passed through a through hole passing through each sheet are connected with the use of a conductive adhesive sheet, a method in which the terminals of wirings passed through a through hole passing through each sheet are press-bonded to each other, is used. Furthermore, a method can be employed, in which a light-emitting element (such as, for example, an organic EL) for converting modulated electric signals into modulated light and a light receiving element (for example, a photoelectric conversion element) for receiving the modulated light and returning the light into the original modulated electric signals are arranged on each substrate to exchange signals between the substrates via light.

[0049] Furthermore, the present method can be employed for not only devices mainly including elements composed of organic materials as in Embodiment 1, but also inorganic semiconductor devices such as silicon devices with processors and memories arranged on substrates, which are made thinner by removing substrates without any functional portions as much as possible.

[0050] Although the IC card composed of the four units has been explained as an example in the present embodiment, the present embodiment is not limited to for IC cards, and is applied to other semiconductor devices, for example, televisions, cellular phones, personal digital assistants etc. Furthermore, the number of units is not to be considered limited to four.

[0051] (Embodiment Mode 4) When each element is composed of a flexible material, flexibility can be provided to the elements themselves, and when these elements are formed and arranged on a flexible sheet substrate, flexibility can be provided to the entire sheet with the respective elements arranged thereon. The flexible

elements can be manufactured by for example, the method described in Embodiment 1. Rolling up the sheet and sealing the openings can manufacture a semiconductor device in the shape of a rod.

[0052] First, on a sheet of substrate, respective elements of a processor 3, a storage element 4, a first sensor 1a, a second sensor 1b, and a display element 2 are formed in a planar arrangement. Next, the substrate on which the respective elements are arranged with wiring provided is rolled up, and the ends are sealed with sealing 9. From among the respective elements, the elements needed to be exposed on the outermost surface when rolled up, such as the display element 2 and a sensor portion, are arranged in consideration of their positions in advance when the elements are arranged on the sheet substrate.

[0053] In a case in which there are any elements on the outermost surfaces or any elements in direct contact with each other, the elements can be coated in advance with a protective film or the like.

[0054] In the present embodiment, FIG. 6 shows a device rounded in such a way that only a display and a sensor portion are exposed on the surface of a semiconductor device in a final shape, the other processor 3, storage element 4, and the second sensor 1b are rolled inward. Although FIG. 6 shows a round sealing portion, the shape of the sealing portion is not particular limited. The inner diameter and outer shape of the semiconductor device in the shape of a rod (a cylinder) can be set provided that the elements or wiring is not destroyed, depending on the flexibility of the substrate after the formation of the elements. Furthermore, with temporary joint in the shape of a rod (a cylinder) without complete sealing, the semiconductor device can be used in the opened state or the rolled state, if necessary. This allows the semiconductor device to, for example, be rounded while carrying (for example, it is also possible to provide the device with a fixture like a pen and stick the device in a breast pocket), and opened in use.

[0055] (Embodiment Mode 5) In a case in which there are components which have a width corresponding to the thickness of the semiconductor device and the same length as one side of the semiconductor device (with an appropriate thickness) in the form of a plate, and the elements constituting the semiconductor device are mounted on one of the components, or are divided and mounted on a plurality of components, one semiconductor device can be formed by combining the respective components, as shown in FIG. 7. FIG. 7 is an example of an IC card. In a case in which the semiconductor device is composed of 110 components S1 to S110, the components S1 to S10 includes only a substrate material and constitute the outer shape, each of the components S11 to S30 is composed of a 10KB RAM memory unit for constituting an ROM with a total capacity of 200 KB and constituting wiring, each of the components S31 to S50 is composed of a 10KB RAM memory unit for constituting an RAM with a total capacity of 200 KB and wiring, and the components S101 to S110 includes only a substrate material and constitute the outer shape. The combination of the 110 components described above constitutes one semiconductor device. A RF coil 5 can be formed by printing after the completion of the combination.

[0056] However, the numbers and shapes of the respective elements and entire components are not to be considered to the present embodiment.

[0057]

[Advantageous Effect of the Invention] The present invention allows respective elements constituting a semiconductor device not only to be arranged in a planar manner, but also to have the total thickness made thinner while stacking in the thickness direction, allowing for more functions provided in the limited space of the semiconductor device than ever before.

[0058] As for the materials constituting the respective elements, for example, organic materials have a slight amount of impurity which less affects the properties of the elements, and is more flexible, as compared with inorganic semiconductor materials. Therefore, the occurrence of the problem that the reliability of the semiconductor device is significantly decreased due to contamination, bending, twisting, etc. can be reduced by all of or as many components as possible from among the components of semiconductor elements such as the

element for recording data, the logic element for processing data, the communication element for exchanging data, the element for storing or generating the energy, the element (sensor) for detecting and accumulating external information or converting the external information into data that is able to be communicated, and the element for displaying the recorded data, which are composed of organic materials.

[0059] A wide variety of elements can be manufactured in a consistent printing process, thereby resulting in a quite simple manufacturing process at low cost, and in addition, allowing for dealing with small-lot production of a wide variety of different products in specification at user's request.

[Brief Description of the Drawings]

[FIG. 1] a diagram illustrating the structure of a conventional IC card.

[FIG. 2] a diagram illustrating an example of the structure of an IC card according to the present invention.

[FIG. 3] a diagram illustrating a process for forming a transistor structure with organic materials according to the present invention.

[FIG. 4] a diagram illustrating an example of the structure of a folded IC card according to the present invention.

[FIG. 5] a diagram of a semiconductor device of a stack of functional units with elements arranged on sheet substrates.

[FIG. 6] a schematic view of a semiconductor device in the shape of a rod, obtained from rolling up a flexible substrate with flexible elements arranged and sealing the portions.

[FIG. 7] a schematic view of a semiconductor device made from the combination of components in the form of a plate.

[Explanation of the Reference Numerals and Signs]

- 1 ... sensor
- 1a ... first sensor
- 1b ... second sensor
- 2 ... display element
- 2a ... display layer
- 2b ... driving circuit
- 3 ... processor
- 4 ... storage element
- 5 ... RF coil
- 6 ... substrate
- 7 ... protective film
- 8 ... substrate
- 9 ... sealant
- 11 ... wiring
- 20 ... IC chip
- 21 ... gate electrode
- 22 ... gate insulating film
- 23 ... source electrode
- 24 ... drain electrode
- 25 ... semiconductor layer

Continued from the front page

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